Journal of Aquatic Animal Health 14:145–148, 2002
American Fisheries Society 2002

COMMUNICATIONS

Efficacy of Potassium Permanganate in Treating Ichthyophthiriasis in Channel Catfish

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Abstract.—Epizootics of ichthyophthiriasis can be controlled with potassium permanganate ($KMnO_4$), but its effectiveness has not been confirmed by controlled studies. The purpose of this study was to determine the concentration of $KMnO_4$ needed to halt an active *Ichthyophthirius multifiliis* infestation in channel catfish *Ictalurus punctatus*. Juvenile channel catfish were exposed to fish infested with *I. multifiliis* until they developed immature trophonts. They were then moved to individual static containers with 2 L of filtered well water, where they were treated with $KMnO_4$ daily for 10 d. The lowest effective dose of $KMnO_4$ required to eliminate theronts was 1.25 mg/L. The results indicate that $KMnO_4$ is effective for controlling *I. multifiliis* epizootics at low concentrations in clean water. However, effective treatment in ponds will be strongly influenced by detoxication of $KMnO_4$ depending on the concentration of easily oxidizable substances in the water.

Ichthyophthirius multifiliis is an external protozoan parasite that invades the skin and gills of freshwater fish and causes a disease known as ichthyophthiriasis, commonly referred to as ich (Schäperclaus 1991). The lifecycle of *I. multifiliis* has been well documented (Beckert and Allison 1967; Schäperclaus 1991). When juvenile or fingerling channel catfish *Ictalurus punctatus* are raised at high densities, an *Ichthyophthirius multifiliis* epizootic can kill the entire fish population (Tucker and Robinson 1990). Various antiprotozoan drugs can be used to kill the infective theront or the detached trophont to stop the reproductive cycle and prevent the spread of the disease to other fish (Tucker and Robinson 1990; Schäperclaus 1991).

There are currently four legal options for use of chemotherapeutants in the United States: (1) the Food and Drug Administration (FDA) has approved the use of the compound as a therapeutant; (2) the therapeutant is the subject of an Investigational New Animal Drug exemption; (3) the therapeutant has been determined by the FDA to be of low regulatory priority; or (4) the therapeutant is not of low regulatory priority but the regulatory action has been deferred pending the outcome of research. Currently only formalin (Formalin-F, Paracide-F, and Parasite-S), oxytetracycline (Terramycin), sulfadimethoxine and ormetroprim (Romet 30), and sulfamerazine (no longer manufactured) are FDA-approved therapeutants, though each approval is for specific uses (Greenlees 1997).

Formalin is the only therapeutant approved for use in protozoan parasite control, but this chemical is not widely used because of high cost and human safety concerns. Copper sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) and potassium permanganate ($KMnO_4$) also are used in protozoan parasite control; however, neither chemical is FDA approved and regulatory action on these compounds has been deferred pending outcome of current research. Copper sulfate is the compound most often used to control ichthyophthiriasis because of its effectiveness (Straus 1993; Schlenk et al. 1998) and low cost, but it can be extremely toxic to fish in water with low alkalinity (Straus and Tucker 1993; Wurts and Perschbacher 1994; Perschbacher and Wurts 1999). As an alternative parasiticide, $KMnO_4$ is more expensive but less toxic to fish (Marking and Bills 1975; Tucker 1987) in low-alkalinity waters, where use of copper sulfate might be unsafe.

The objective of the present study was to determine the concentration of $KMnO_4$ needed to stop an active *I. multifiliis* epizootic in juvenile channel catfish under controlled laboratory conditions. This efficacy information will be useful in formulating safe treatment rates for channel catfish culture and is required by the FDA in support of a New Animal Drug Approval.

Methods

Juvenile channel catfish (13.6 g ± 1.5 SD) were placed in a 38-L aquarium filled with 30 L of well

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Received July 24, 2001; accepted January 7, 2002

TABLE 1.—The treatment rate, calculated concentration of Mn, measured daily Mn concentration, and daily residual potassium permanganate ($KMnO_4$) concentration (after 24 h) for each treatment during the 10-d study on the efficacy of $KMnO_4$ in treating *I. multifiliis.* All values are milligrams per liter (±SD where shown).

Treatment rate	Calculated Mn	Measured Mn[a]	Residual $KMnO_4$[b]
0	0	0.005 ± 0.006	0.019 ± 0.020
0.5	0.174	0.174 ± 0.008	0.101 ± 0.063
0.75	0.261	0.247 ± 0.017	0.162 ± 0.078
1.0	0.348	0.338 ± 0.021	0.227 ± 0.064
1.25	0.434	0.406 ± 0.029	0.324 ± 0.122
1.5	0.521	0.499 ± 0.036	0.344 ± 0.146

[a] Based on 27 or less Mn measurements per treatment, depending on fish mortality.
[b] Based on 48 or less residual $KMnO_4$ measurements per treatment, depending on fish mortality.

TABLE 2.—Mortality of channel catfish from ichthyophthiriasis at the end of the 10-d study on the efficacy of potassium permanganate ($KMnO_4$) in treating *I. multifiliis*; $N = 3$ per treatment.

Treatment (mg/L)	Mortality (number of fish)	Comments
0	3	Controls died on days 7, 8, and 10
0.5	2	Surviving fish thoroughly infested with trophonts (>75/cm^2)
0.75	1	Surviving fish thoroughly infested with trophonts (>75/cm^2)
1.0	0	No trophonts found on gills; 2 fish had a few trophonts on the skin, and these had very thick cyst walls
1.25	0	No trophonts found on gills or skins
1.5	3	Apparently died from excessive $KMnO_4$ exposure

water. Additional well water was passed through a 20-μm (pore-size) filter and held in a 200-L plastic reservoir to use as replacement water for individual treatment containers throughout the study. The aquarium was equipped with an air stone and an established outside biological filter containing pea gravel. The fish were not fed during the study.

In a separate aquarium, a locally obtained strain of *I. multifiliis* was maintained as in Straus and Griffin (2001). Several thoroughly infested fish from this aquarium were transferred into the aquarium containing the uninfected juvenile channel catfish. After 10 d, the juvenile channel catfish were sparsely covered with mature trophonts. The fish were then transferred to randomly chosen 3.8-L glass jars containing 2 L of filtered well water, each jar containing one fish.

Treatment concentrations ranged from 0.50 to 1.50 mg/L $KMnO_4$ in increments of 0.25 mg/L. Treatments were administered daily after a complete water exchange; untreated controls also received a complete water exchange at this time. There were three replications per treatment. The study was terminated when the control fish died. At the conclusion of the study, the entire body surface of each surviving fish was visually examined and all gill arches were microscopically examined for the presence of trophonts; trophonts are typically 0.5–1.0 mm in diameter.

Total ammonia nitrogen and nitrite-nitrogen were monitored daily with a Hach kit (model FF-1A) before the total water exchange and retreatment. An air stone in each container maintained dissolved oxygen levels at greater than 75% saturation. Temperature (17 ± 2.5°C) and pH (8.5 ± 0.1) were monitored daily during the study. Total alkalinity (standard acid titration method; APHA et al. 1998) and total hardness (EDTA titration method; APHA et al. 1998) concentrations, as determined from the water in the plastic reservoir, were 213.1 and 120.9 mg/L (as $CaCO_3$), respectively.

The $KMnO_4$ demand of the water in the plastic reservoir was determined by the method of Engstrom-Heg (1971). Before each water exchange, samples were taken from each jar for immediate determination of residual $KMnO_4$ (Engstrom-Heg 1971). Water was sampled immediately after each treatment to measure total Mn concentration (APHA et al. 1998) with a Thermo Jarrell Ash (model AA Scan 1) atomic absorption spectrophotometer equipped with a graphite furnace.

Results and Discussion

The measured concentration of Mn for each treatment was similar to the calculated concentration, which suggests that little Mn was absorbed by fish skin or mucus or adhered to the glass treatment containers (Table 1). The residual $KMnO_4$ measured demonstrate that less $KMnO_4$ was present 24 h after treatment. Therefore, any theronts that developed during this period could have been exposed to concentrations that might influence their growth.

The study was terminated after 10 d when all control fish had died from ichthyophthiriasis (Table 2). No trophonts were found during examination of fish exposed to 1.25 mg/L $KMnO_4$. Treatment with 1.0 mg/L $KMnO_4$ greatly reduced the occurrence of trophonts on the fish skin, and these

external trophonts had thick cyst walls; no trophonts were present on the gills of these fish. Exposure to $KMnO_4$ at concentrations less than 1 mg/L resulted in thorough infestation, which was debilitating or caused death.

By day 8, the fish in the 1.5 mg/L $KMnO_4$ treatment displayed sporatic episodes of tetany, and patches of brown-stained skin were evident. All of these fish died by the end of the study, perhaps from excessive permanganate oxidative damage to gill tissue. The brown stain was similar in color to that of manganese dioxide, a reduction product of $KMnO_4$. By day 9, one of the fish in the 1.25 mg/L $KMnO_4$ treatment displayed a brief episode of tetany; however, no fish died at this concentration.

Potassium permanganate is widely used and a wealth of data are available on its uses in aquaculture (Duncan 1978). A strong oxidizer, its effectiveness is dictated by the amount of easily oxidizable material in the water (Marking and Bills 1975). Engstrom-Heg (1971) developed a spectrophotometric method for measuring the amount of permanganate reduced by substances in the water, commonly called the $KMnO_4$ demand. Boyd (1979) described a 15-min visual method that gave similar results. Tucker (1989) proposed a procedure for estimating the amount of $KMnO_4$ needed to treat a pond by multiplying the 15-min $KMnO_4$ demand by 2.5.

The $KMnO_4$ demand for the filtered well water used in the present study was 0.40 mg/L. According to Tucker (1989), the estimated treatment rate would be 1.0 mg/L $KMnO_4$, which is less than the effective treatment rate of 1.25 mg/L of the present study. However, the estimated treatment rate was developed mainly for waters of high organic content and not for fine-tuning treatment rates in pure, clean waters. The 1.0 mg/L $KMnO_4$ treatment in the present study prevented fish mortality, an observation consistent with that reported by Tucker (1989) in establishing the recommended treatment rate.

The effective treatment concentration of the present study (1.25 mg/L $KMnO_4$) is slightly greater than that reported by Straus and Griffin (2001) for preventing an initial infestation of *I. multifiliis* in channel catfish (1.0 mg/L $KMnO_4$). In the present study, the established outbreak of ichthyophthiriasis may have required a greater treatment concentration because of a greater parasite load and therefore the presence of more organic matter in the water.

The mode of action for the efficacy of $KMnO_4$ is oxidation of organic compounds. Although the waters of the present study were of high alkalinity and medium hardness, such properties are not thought to affect oxidation of organic compounds by $KMnO_4$. Therefore, efficacy of this compound should be similar in waters of low alkalinity and hardness.

The results of the present study are applicable to clean water systems with low $KMnO_4$ demands and do not represent the rates that will be useful in treating ichthyophthiriasis under field conditions because other factors influence effective treatment protocols in the field. Potassium permanganate is reduced by reactions with easily oxidizable substances in the water; the rate of detoxification depends on the concentration of these substances and will vary for each pond. Also, multiple applications are needed for an effective treatment because only the infective free-swimming theront or the detached trophont can be killed, and the lifecycles of individual *I. multifiliis* organisms are not synchronized.

The low margin of safety between the effectiveness of controlling ichthyophthiriasis and mortality in the present study is considered to reflect the daily exposure to $KMnO_4$ for 10 d, which differs from the normal treatment regime of treating every other day as needed (3–5 treatments). Fish mortality in the 1.5 mg/L treatment was attributed to excessive oxidation of the gill tissue by $KMnO_4$. Also, the data of Tucker (1987, 1989) suggest that the margin of safety increases as the $KMnO_4$ demand of the water increases. Future research should determine the margin of safety versus effectiveness of $KMnO_4$ when administered every other day in conditions covering a range of organic matter concentrations.

Acknowledgments

This research was supported in part by a grant from the International Association of Fish and Wildlife Agencies. Special thanks to Kelly Gill and Jan Simpson for technical help throughout the studies. Jerry Ludwig, Kenneth B. Davis, and Craig Tucker provided critical reviews of the manuscript. Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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